EARTHQUAKES

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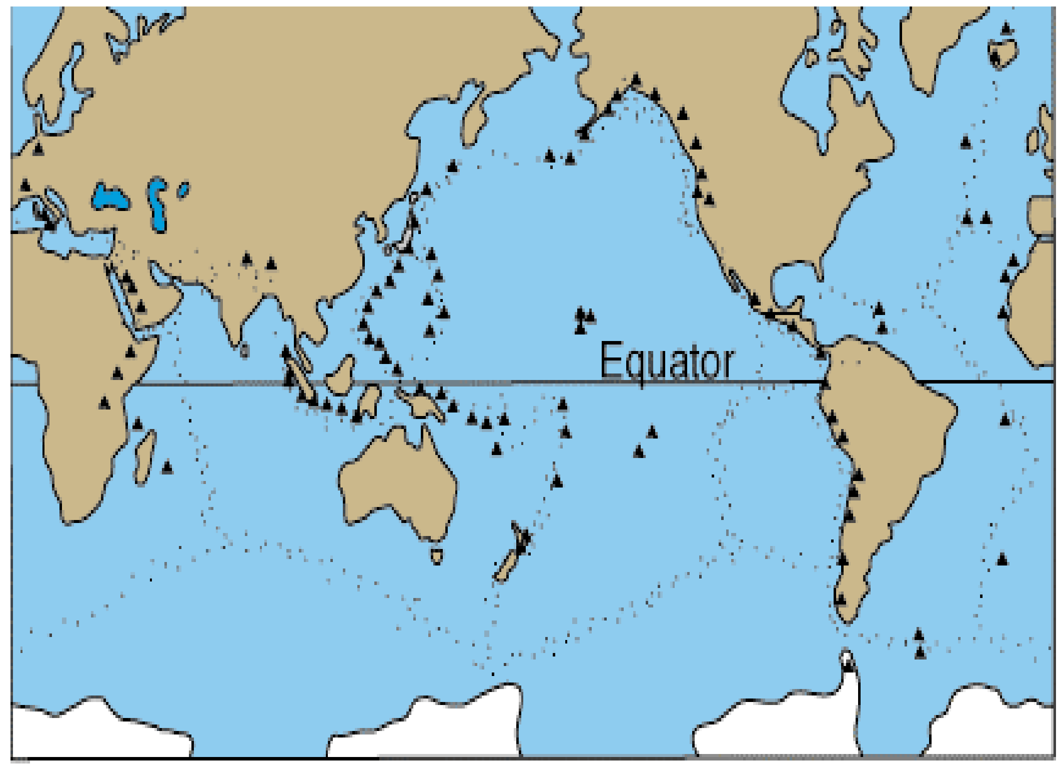
PREPARED TO MEET SOUTH CAROLINA’S NEW SCIENCE STANDARDS

EARTHQUAKES

An earthquake is a sudden motion or shaking of the Earth as rocks break and move. This movement causes seismic waves to move along the surface of the Earth and move through the Earth.

EARTHQUAKES AND PLATE TECTONICS

- The world’s earthquakes and volcanoes are concentrated along narrow zones that define the boundaries of the plates. The interiors of the plates are generally free of earthquakes, notable exceptions being the 1811-12 earthquake at New Madrid, Missouri and the 1886 earthquake at Charleston, South Carolina.



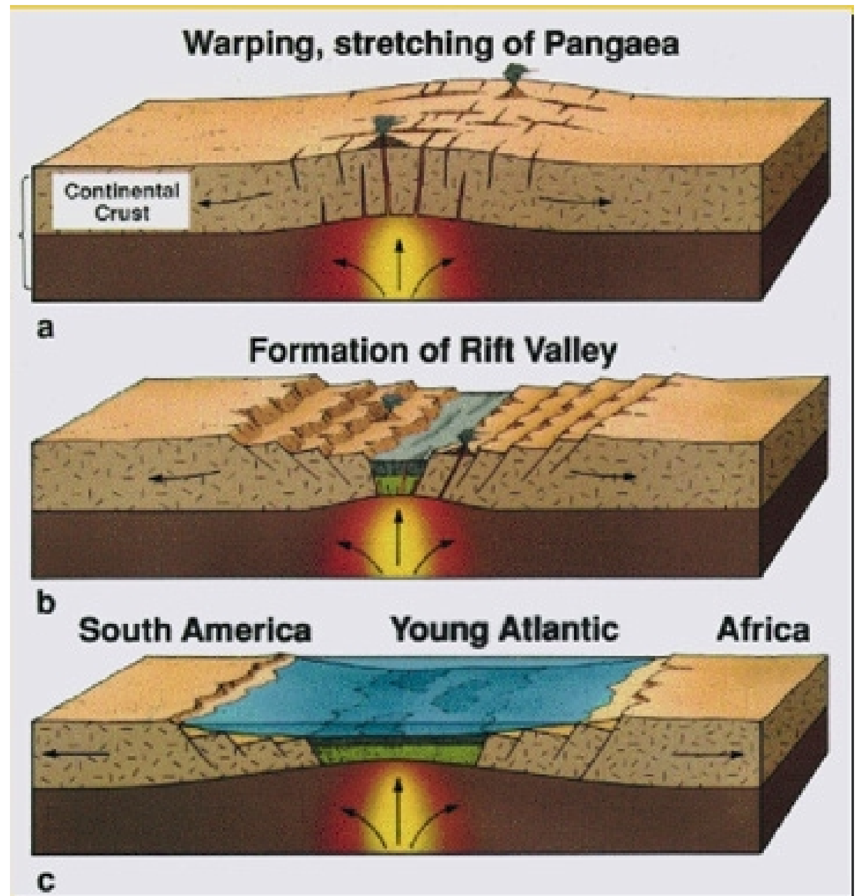
Global distribution of volcanoes (▲) and earthquakes (· · ·) based on Simkin and others (1989).

MAJOR EARTHQUAKE ZONES

- Divergent boundaries
- Convergent boundaries
- Transform boundaries

DIVERGENT BOUNDARIES

- Mid-ocean ridges and rift valleys in continents are divergent boundaries. New crust is formed at divergent boundaries. Examples are the Mid-Atlantic Ridge and rift valley of East Africa. Volcanism tends to be less explosive. Earthquake activity is minor and occurs at shallow depths. Intensities are generally small, because the crust is thin and because strain is constantly being released, so that large amounts of strain cannot build up.

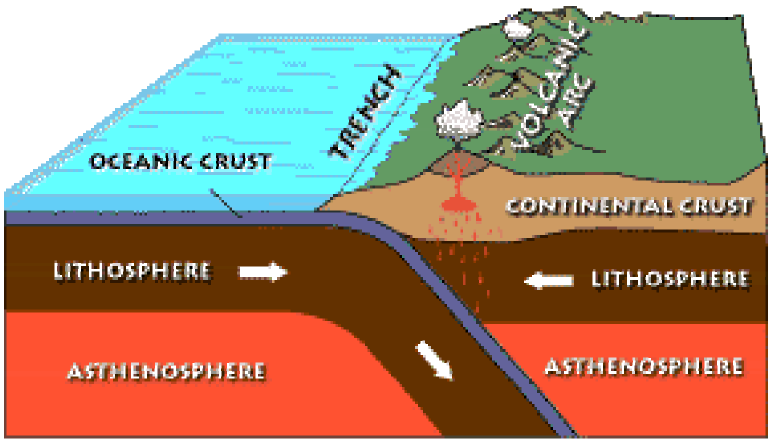


CONVERGENT BOUNDARIES

- Oceanic-continental plate boundary
- Oceanic-oceanic plate boundary
- Continental-continental plate boundary

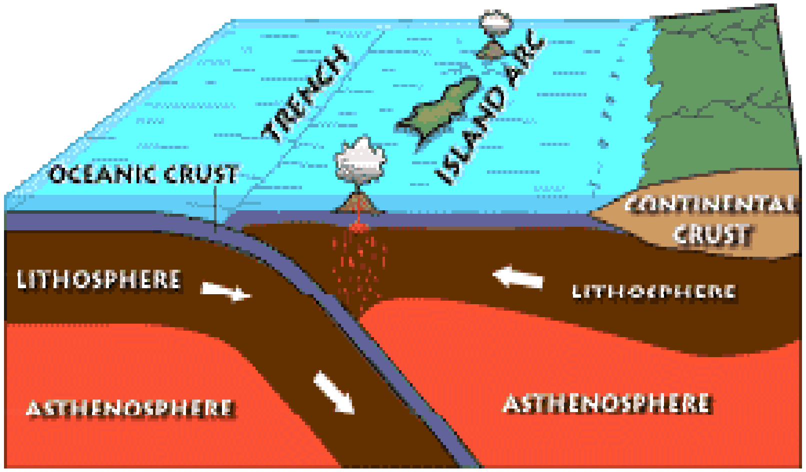
OCEANIC-CONTINENTAL PLATE BOUNDARY

- When an oceanic plate and a continental plate collide, the oceanic plate is subducted below the continental plate. Examples include the Cascade Mountains where the Pacific plate is being subducted below the North American plate and the Andes Mountains where the Pacific plate is being subducted below the South American plate. Earthquakes can be shallow, intermediate, or deep. Associated volcanism can be very explosive. Deep ocean trenches are formed at the boundary.



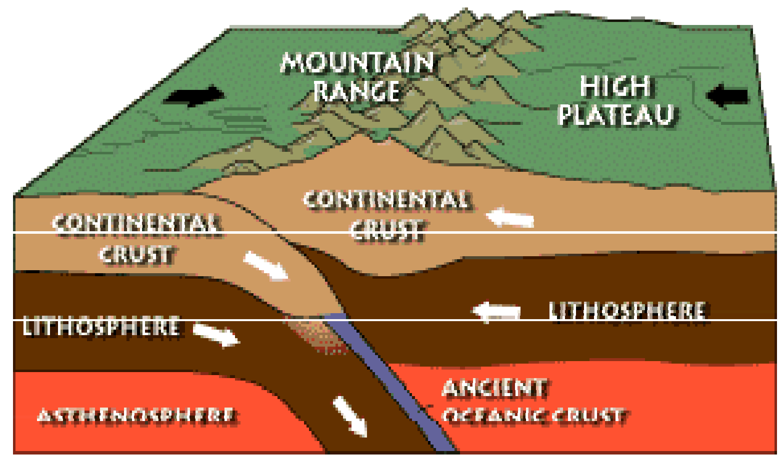
OCEANIC-OCEANIC PLATE BOUNDARY

- When two oceanic plates collide, the older and denser plate is subducted. This type of boundary is similar to the oceanic-continental plate boundary. Examples are the Philippine Islands and the Aleutian Islands. Earthquakes can be shallow, intermediate, or deep. Associated volcanism is usually explosive. A deep ocean trench is formed at the boundary and island arcs occur over the subducting plate.



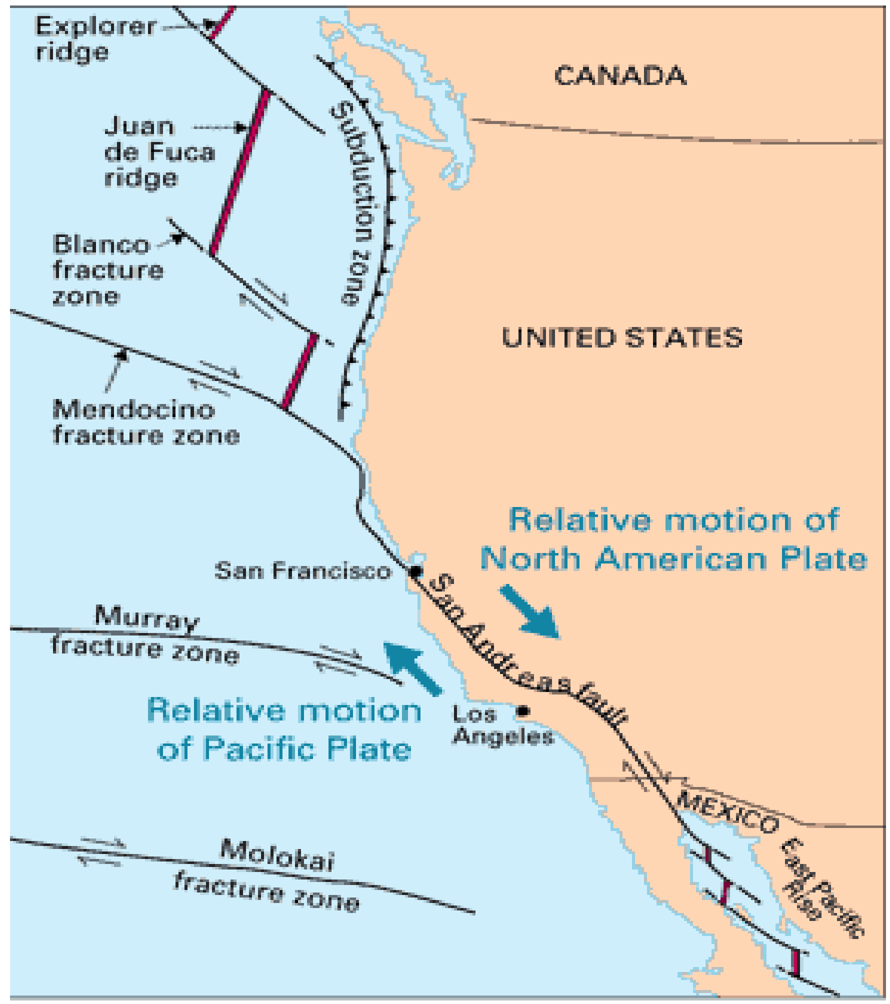
CONTINENTAL-CONTINENTAL PLATE BOUNDARY

- When two continental plates collide, the two continental crusts are folded, faulted, and piled upon each other. The Himalayan Mountains are an example of a continental-continental plate boundary. Shallow, intermediate, and deep earthquakes are associated with this zone.



TRANSFORM BOUNDARIES

- At transform plate boundaries, plates grind past each other. Earthquake activity occurs as shallow-focus events unaccompanied by volcanic activity. Large earthquakes can occur because large amounts of strain caused by friction can build up before being released by an earthquake. The San Andreas fault in California, where the North American and Pacific plates scrape by each other, is an example of a transform boundary.



HOW CAN PLATE TECTONICS HELP PREDICT EARTHQUAKES?

- The majority of earthquakes occur at plate boundaries., we can therefore predict the general area where earthquakes are likely to occur but we cannot say exactly when an earthquake will occur.

SEISMIC WAVES

Body waves: travel through Earths interior

- P-Waves
- S-Waves

Surface waves: travel along the surface of the earth

- Rayleigh Waves
- Love Waves

TYPES OF BODY WAVES

- P-Wave (primary wave) is a **compressional wave**, which compresses and dilates the rock as it travels forward through the Earth. This is very similar to the movement of a spring. Compressional waves can propagate through solids, liquids and gases because all three can sustain changes in density. They are called primary waves because they travel faster and are the first waves to be recorded after the occurrence of an earthquake. The speed at which P waves travel depends upon the properties of the matter through which they propagate. In general, the less dense the matter, the slower the waves.
- S-Wave (secondary wave) is a **transverse** or **shear** wave which shakes the rock sideways as it advances at barely more than half the P-wave speed. S-waves only transmit through solids where particles have enough cohesion to be pulled (perpendicular to the direction of travel) by one another.

SURFACE WAVES

Surface waves are the second type of wave. These waves are produced from the arrival of P and S waves at the surface and produce most of the destruction. They are slower than P and S waves and can only travel on the surface of the Earth.

Rayleigh waves produce a rolling motion analogous to waves on the surface of a body of water. An object on the surface will experience both an up-and-down motion transverse to, and a back-and-forth motion parallel to, the propagation direction of the Rayleigh wave. The two components combine to produce a rolling, elliptical motion.

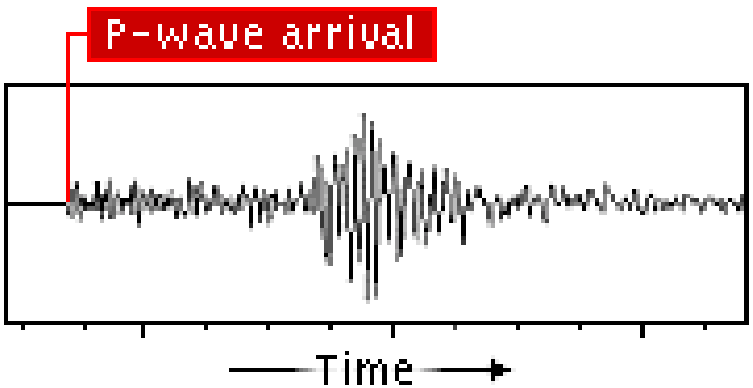
Love waves produce transverse motion -- perpendicular to the direction of wave propagation -- in a horizontal orientation only. This kind of horizontal shearing can be devastating to the foundations of buildings

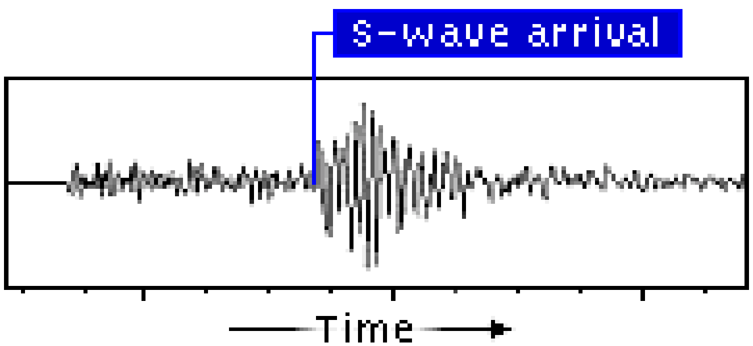
MEASURING EARTHQUAKES

- Scientists use seismometers (seismographs) to measure the strength and location of earthquakes. Seismometers measure the arrival time of P and S waves from the earthquake to the seismic station. P-waves travel faster than S-waves and are the first waves recorded. The arrival times of P and S waves are used to calculate the distance from the seismic station to the earthquake. Likewise, the amplitude of the S-wave is used to calculate the magnitude of an earthquake.

SEISMOGRAMS

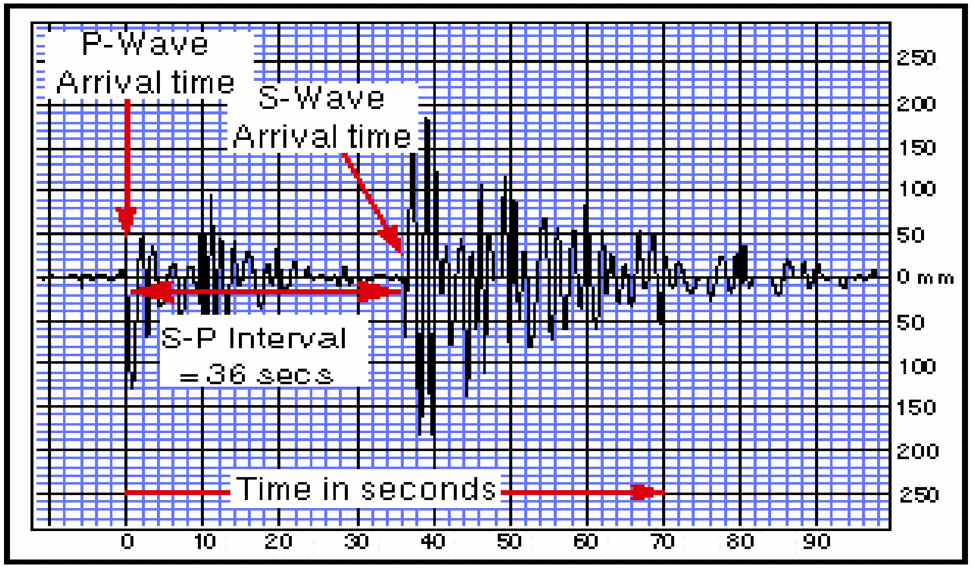
- Seismograms are recordings of a seismograph, a machine that detects and records vibrations of the earth. The figures on the right are seismograms illustrating the different arrival times of P waves and S waves.





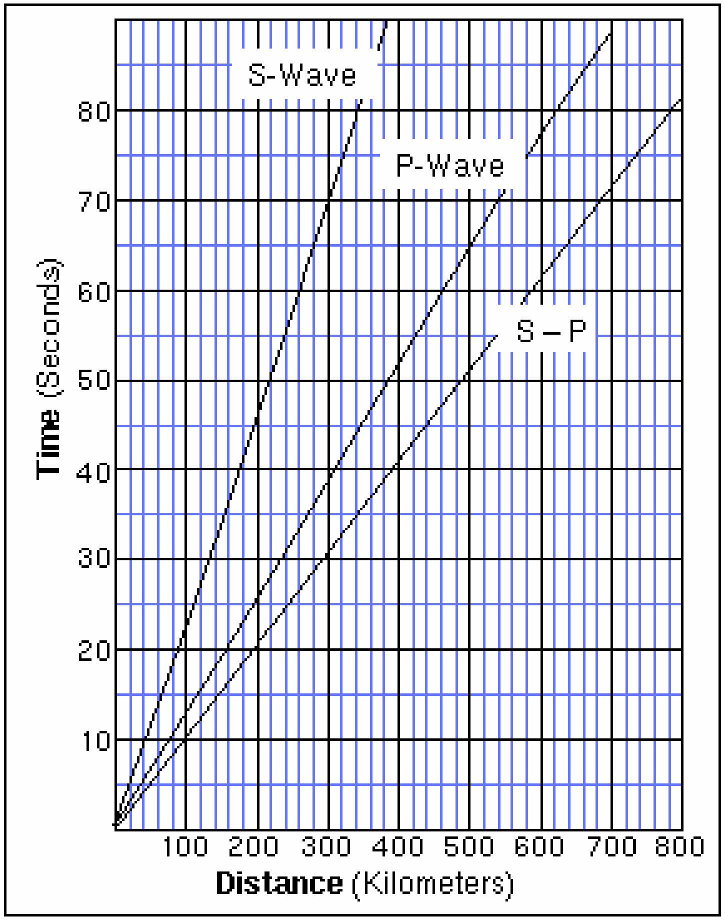
LOCATING THE EPICENTER OF AN EARTHQAUKE

- In order to locate the epicenter of this earthquake, you need to estimate the time interval between the arrival of the P and S waves (the S-P interval) on the seismograms from three different stations. You have to measure the interval to the closest second and then use a graph to convert the S-P interval to the epicentral distance. On the sample seismogram at the right, the vertical lines are spaced at 2 second intervals and the S-P time interval is about 36 seconds.



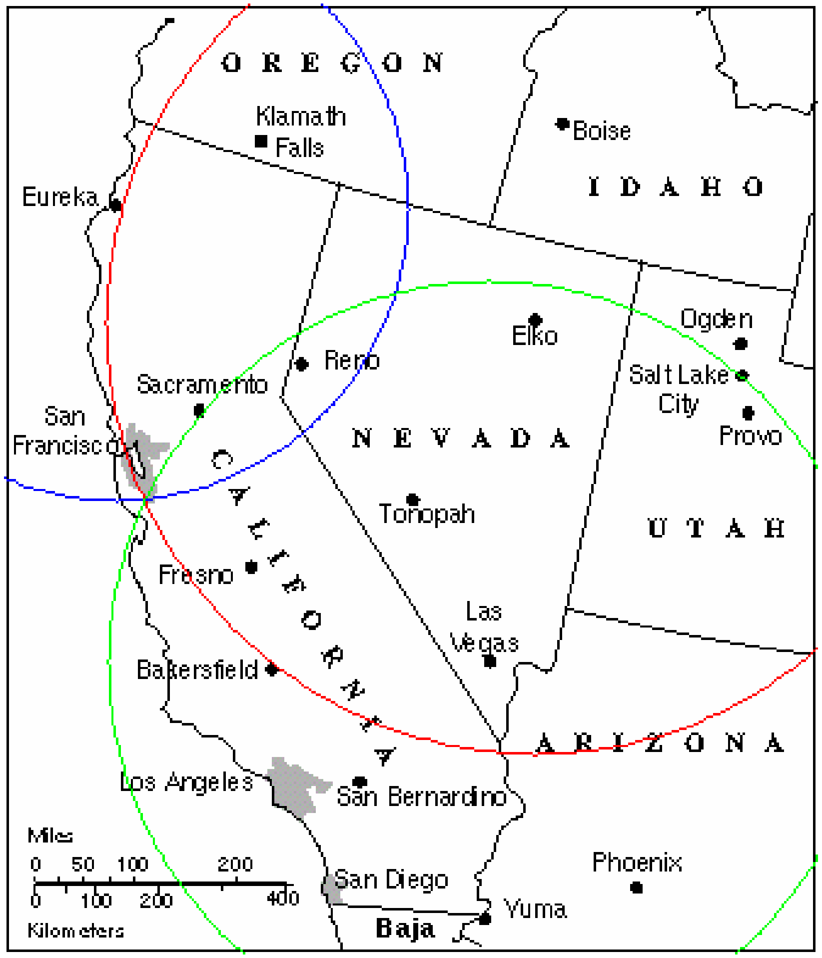
DETERMINING THE EARTHQUAKE DISTANCE

- You can now determine the distance from each seismic recording station to the earthquake's epicenter by using the known times of travel of the S and P waves.
- Examine the figure to the right, a graph of seismic wave travel times. There are three curves on the graph. The upper curve shows S wave travel-time versus distance, the center one shows P wave travel time versus distance, and the lower one shows the variation in distance with the difference of the S and P travel times. An S wave takes approximately 70 seconds to travel 300 kilometers. A P wave takes less than 40 seconds to travel the same distance.



TRIANGULATION OF THE EPICENTER

- The map to the right depicts a the earthquake region. The three epicentral circles whose radii correspond to the distances determined are drawn around the seismic recording stations. The intersection of the three circles is the epicenter of the earthquake. Please see http://vcourseware5.calstatela.edu/Geolabs for exercises in determining the epicenter of an earthquake and its Richter magnitude.



MEASURING THE STRENGTH OF AN EARTHQUAKE

- The magnitude of an earthquake is an estimate of the total amount of energy released during fault rupture. The Richter Magnitude Scale was introduced into the science of seismology in 1935, by Dr. C. F. Richter of the California Institute of Technology. The Richter Scale uses the records (seismograms) of an earthquake's shock waves as the means for comparing magnitudes of earthquakes. The Richter magnitude of an earthquake is a number; about 3 for earthquakes that are strong enough for people to feel and about 8 for the Earth's strongest earthquakes. Although the Richter scale has no upper or lower limits, earthquakes greater than 9 in Richter magnitude are unlikely. The most sensitive seismographs can record nearby earthquakes with magnitude of about -2 which is the equivalent of stamping your foot on the floor.